EDGECOMBE COUNTY LANDFILL
ASSESSMENT OF CORRECTIVE MEASURES
(PERMIT # 33-01)
TARBORO, NORTH CAROLINA

S&ME Project No. 1054-07-241

Prepared For:

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I hereby certify this 26th day of June, 2008, that this report was prepared by me or under my direct supervision.

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EXECUTIVE SUMMARY

Edgecombe County (County) currently operates a construction and demolition (C&D) debris landfill on top of a closed municipal solid waste (MSW) landfill in general accordance with North Carolina Department of Environment and Natural Resources (NCDENR) Solid Waste Facility Permit No. 33-01. The landfill is located off of State Road 1601 (Colonial Road), south of Tarboro, North Carolina. The C&D landfill is used for the disposal of waste generated within Edgecombe County and from surrounding counties.

The NCAC 2L Groundwater Quality Standards (2L Standard) for several target constituents in groundwater have been exceeded at the facility near the north-northeastern property boundary. The nearest receptor north-northwest of the facility is Jerry's Creek.

In order to characterize the nature and extent of the release at the Edgecombe County Landfill, S&ME previously preformed additional geologic and hydrogeologic site characterization. The limits of waste placed at the former MSW landfill site and the contaminant distribution in the groundwater within the landfill were also evaluated for the potential of contaminant migration to and beyond the waste boundary. Recent and historical groundwater and surface water analytical data at the landfill were reviewed to identify constituents of concern and trends in their concentration and distribution. In addition, S&ME personnel identified possible receptors within 1,500 feet of the waste disposal unit. S&ME also characterized and delineated the extent of the contaminant plume in the area of groundwater compliance monitor wells by installing thirty-five non-network wells designated P-4 through P-38.

This Nature and Extent Study (NES) has identified five organic compounds and one inorganic analyte as the constituents of concern at the Edgecombe County Landfill. These constituents include the VOCs: vinyl chloride, benzene, cis-1, 2-dichloroethene, trichloroethene, and 1, 4-dichlorobenzene, as well as the metal cobalt.

The results of this NES indicate that the area impacted by these constituents of concern (COC) is limited to the Edgecombe County solid waste facility boundary. The COC concentrations do not appear to have adversely impacted surface water quality. Concentrations of the organic and inorganic COCs detected within the plume are relatively low. In addition, there are no identified drinking water wells located downgradient of the waste disposal unit. Therefore, the level of risk to human health is expected to be low.

NCDENR, Division of Waste Management (DWM), Solid Waste Section (SWS) Solid Waste Rules defined under 15A NCAC 13B .1635 require that the County perform and assessment of corrective measures (ACM) to address the release from the landfill. This ACM Report was prepared by S&ME Inc. (S&ME) on behalf of the County to evaluate "The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination; the time required to begin and complete the remedy; the costs of remedy implementation; and the institutional requirements such as State and Local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s).

Several potential solutions or corrective measures could be implemented to address the migration of groundwater contaminants beyond the compliance boundary. The following techniques could be considered as possible effective corrective measures.

- Institutional Controls – Monitored Natural Attenuation, Access Restrictions, and Deed Restrictions
- Groundwater Collection –Pumping Wells/Hydraulic Barrier and Interceptor Trenches
- Gas Extraction – Volatilization
- On-Site Treatment:
    - <u>Physical</u>: Air Stripping, Carbon Adsorption, Filtration, Ion Exchange, Reverse Osmosis
    - <u>Chemical</u>: Neutralization, Physical/Chemical Separation
    - <u>Biological</u>: Constructed Wetlands
- In-Situ Isolation – Surface Cap / Grade and Barrier / Containment Wall
- Off-Site Disposal – POTW Discharge
- On-Site Disposal – Discharge to Surface Water

Of these potential measures, the County will choose the most feasible method which will achieve the combined goals of protection of human health and the environment with a reasonable allocation of County resources.

1. INTRODUCTION

1.1 Purpose

Edgecombe County (County) currently operates a construction and demolition (C&D) debris landfill on top of a closed municipal solid waste (MSW) landfill in general accordance with North Carolina Department of Environment and Natural Resources (NCDENR) Solid Waste Facility Permit No. 33-01. The County performs landfill gas monitoring on a quarterly basis and performs semi-annual groundwater and surface water monitoring from a monitor well network consisting of seven monitor well locations surrounding the boundary of the waste disposal unit, two surface water sample locations and eleven gas monitoring wells. The network of monitor wells was designed for compliance monitoring in the event that concentrations of contaminants originating from the landfilled waste materials were released to the environment. Groundwater and surface water compliance monitoring is performed to comply with the requirements of North Carolina Solid Waste Management Rules (Solid Waste Rules), 15A NCAC 13B § .600, §.1632 and §.1634 of the Solid Waste Rules.

Volatile organic compounds (VOCs) and inorganic constituents have been detected above North Carolina groundwater protection standards in groundwater samples collected from groundwater compliance monitoring points used to monitor the Edgecombe County Landfill. In addition, statistical evaluation of groundwater monitoring data indicates a release of VOCs and inorganic compounds from the landfill.

NCDENR, Division of Waste Management (DWM), Solid Waste Section (SWS) Solid Waste Rules defined under 15A NCAC 13B .1635 require that the County perform and assessment of corrective measures (ACM) to address the release from the landfill. This ACM Report was prepared by S&ME Inc. (S&ME) on behalf of the County to evaluate "The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to residual contamination; the time required to begin and complete the remedy; the costs of remedy implementation; and the institutional requirements such as State and Local permit requirements or other environmental or public health requirements that may substantially affect implementation of the remedy(s)," as per 15A NCAC 13B .1635.

1.2 General Site Description

1.2.1 Location

The Edgecombe County Landfill is owned and operated by Edgecombe County. The landfill is located off of State Road 1601 (Colonial Road), south of Tarboro, North Carolina. The landfill location and site vicinity are shown on **Figure 1**. The active C&D landfill is accessed off of Colonial Road and is regulated under NCDENR Solid Waste Facility Permit No. 33-01. The C&D landfill is used for the disposal of waste generated within Edgecombe County and from surrounding counties. The C&D landfill is located over an existing closed MSW landfill cell. The C&D landfill and closed MSW landfill are bounded by Jerry's Creek to the north and by woodlands to the west and south-

southwest. Agricultural fields are located immediately adjacent to the landfill facility property to the south and Colonial Road is immediately adjacent to the east. Across Colonial Road farther to the east is an Edgecombe County MSW convenience center, MSW transfer station (Permit No.33-02T), borrow areas for landfill cover soils and collection areas for tires and white goods for shipment to off-site vendors. Three residential single-family homes are located across Colonial Road to the northeast.

A closed pre-Subtitle D Landfill (northern old landfill), which stopped receiving waste in 1979, is located just north of the active landfill and north of Jerry's Creek. The northern old landfill is identified as Facility No. NONCD0000653 on the North Carolina Inactive Hazardous Sites Branch (IHSB) Inactive Hazardous Waste Sites Inventory and is located between Jerry's Creek and Wright's Creek off of Colonial Road. Wright's Creek is present along the northern property of the northern old landfill and converges with Jerry's Creek to the east of the northern old landfill.

Figure 2 is a site map illustrating site features. For the purposes of this report, the "landfill" or "waste disposal unit" refers to the Edgecombe County Landfill Facility located south of Jerry's Creek at 1601 Colonial Road comprised of the active C&D landfill unit and the underlying closed MSW unit.

1.2.2 Physical Site Characteristics

An understanding of the physical site characteristics was developed by S&ME through the characterization of the nature and extent of the release from the landfill as reported in the Nature and Extent Study Report submitted to the SWS in June 2008.

The local surface water features in the immediate vicinity of the landfill facility include: Jerry's Creek; Wright's Creek; the drainage features in the active landfill area including a former sediment basin; and the farm pond located in the southeast corner of the site. The undisturbed natural topography in the areas surrounding the waste disposal units at the facility is characterized as gradual to moderate slopes toward these local surface water features. The surface of the landfill generally mimics these natural slope gradients and also discharges to these surface water features. Jerry's Creek is the primary receptor of surface water runoff from the landfill. Some areas of the landfill facility drain surface water directly to Jerry's Creek, while much of the central portion drains to a topographic "horseshoe" feature in the northern boundary of the landfill. A sedimentation pond which is a remnant of former MSW operations collects the surface drainage in this area. Infiltration and percolation into the upper soil horizon is expected to be moderate due to the sandy loam content within this stratum. The uppermost aquifer underlying the landfill is expected to discharge to the local surface water features. During periods of rainfall with high surface water runoff, Jerry's Creek, Wright's Creek, the sediment pond, the southwest perimeter trench, and the farm pond may recharge the aquifer. Surface water features are shown on **Figure 2**.

The landfill facility is within the Coastal Plain Physiographic Region of North Carolina that is located between the uplands of the Piedmont and the Atlantic Ocean. Investigations of the Coastal Plain Region have identified as many as ten aquifers separated by nine confining units. However, these aquifers can basically be divided into three major deep aquifer systems in North Carolina: the Quaternary Aquifer System, the

Tertiary Aquifer System, and the Cretaceous Aquifer System. Each of these three major aquifer systems are separated from each other by units of lower permeability composed of clays and silts. The Quaternary Aquifer is composed of surficial deposits of sandy silt and clay. The Tertiary Aquifer is composed of glauconitic sands, clayey sands, and limestone. The Cretaceous Aquifer is composed of sand, silty and clayey sand, and clay separated by confining units of clay and silt.

The uppermost aquifer at the site is unconfined and is found in the silty sands of the Quaternary-age Sunderland formation. These formations are generally less than 50 feet thick, with an average of 20 to 30 feet and consist of yellow silty sand and sandy clays. This aquifer is recharged by inflow from upgradient areas and by infiltration of precipitation. The Tertiary-age Yorktown clay layer, encountered at 13 to 24 feet below the original ground surface, appears to act as a confining layer below the landfill. The Yorktown Formation lies beneath the surficial sediments and consists of 30 to 60 feet of blue gray silty clay with sandy clay, shell beds and fine sands. The Yorktown is extensive throughout the county forming an almost continuous layer. In some areas, water may be "perched" over the Yorktown clays beneath the Quaternary sands, rather than forming a true unconfined aquifer.

2. NATURE AND EXTENT STUDY

2.1 Nature and Extent Summary

As a result of several network compliance monitoring wells exceeding the North Carolina established 2L Standard and/or GWPST, Edgecombe County Landfill as defined under NC DENR Permit #33-01 completed a Nature and Extent Study (NES). A Nature and Extent Study Report was submitted to the Solid Waste Section of NCDENR in June of 2008 documenting the exceedances of the 2L Standards and/or GWPSTs at the Edgecombe County Landfill.

In order to characterize the nature and extent of the release at the Edgecombe County Landfill, S&ME preformed additional geologic and hydrogeologic site characterization. The limits of waste placed at the former MSW landfill site and the contaminant distribution in the groundwater within the landfill were also evaluated for the potential of contaminant migration to and beyond the waste boundary. Recent and historical groundwater and surface water analytical data at the landfill were reviewed to identify constituents of concern and trends in their concentration and distribution. In addition, S&ME personnel identified possible receptors within 1,500 feet of the waste disposal unit. S&ME also characterized and delineated the extent of the contaminant plume in the area of groundwater compliance monitor wells by installing thirty-five non-network wells designated P-4 through P-38.

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The results of this NES indicate that the area impacted by these constituents of concern (COC) is limited to the Edgecombe County solid waste facility boundary. The COC concentrations do not appear to have adversely impacted surface water quality. Concentrations of the organic and inorganic COCs detected within the plume are relatively low. In addition, there are no identified drinking water wells located downgradient of the waste disposal unit. Therefore, the level of risk to human health is expected to be low. The following is a summary of the Nature and Extent Study findings and results, the constituents of concern at the facility, and conclusions:

- The geochemical leachate indicator parameters detected in groundwater samples collected from temporary piezometers and monitor wells were generally more elevated in the downgradient samples, along the northern property boundary, than in the upgradient samples. These data suggest that leachate is contributing to the contamination observed in the downgradient piezometers and wells.

- Air gas contaminant concentrations detected in the monitor wells MW-5 and MW-5S may indicate migration of landfill gas from the waste disposal unit to this area.

- According to the receptor survey, two potable wells used for drinking water purposes were identified at least 1,200 feet from the waste disposal unit. These well locations are within the receptor survey 1,500-foot radius. However, the potable well locations are upgradient of the landfill based on the groundwater potentiometric maps.

- Five organic compounds and one inorganic constituent have been determined to be the constituents of concern at the landfill. These organic compounds include the VOCs: vinyl chloride, benzene, cis-1, 2-dichloroethene, trichloroethene, and 1,4-dichlorobenzene, as well as the inorganic constituent cobalt.

- Historical analytical data indicate that at least one contaminant plume may exist at the landfill. It appears that the source area(s) for the contaminant plume are located within the landfilled waste and the contaminant plume appears to be migrating outside of the waste boundary, north-northeast toward Jerry's Creek.

- The downgradient extent of the groundwater contaminant plume has been delineated north of the landfill and the contaminant plume is contained within the facility boundaries.

- No organic constituents of concern were detected in the groundwater sample collected from the deep monitor well MW-5D. It appears that the contaminant plume located within the facility may be confined to the surficial, uppermost aquifer.

- It appears that at least one separate contaminant plume may exist at the northern old landfill located north of Jerry's Creek. Although the contaminant plume located within the northern old landfill has been largely unexplored, it appears to be migrating southeast toward Jerry's Creek and northeast toward Wright's Creek. The contaminant plume migrating from the northern old landfill may or may not be contained within the facility boundaries.

- Historical surface water and temporary piezometer data indicate that the topographically low area located along Jerry's Creek may be acting as a hydraulic barrier between the two contaminant plumes.

The nature of impacts to the hydrogeologic regime at the Edgecombe County Landfill facility is primarily from organic constituents. In conjunction with the preparation of this report, S&ME is preparaing a Corrective Action Plan to implement the County's selected remedies to restore groundwater quality at the facility. Until the revised Water Quality Monitoring Plan associated with the facility's Corrective Action Plan is approved, it is recommended that the facility continue with the semi-annual groundwater monitoring program already underway at the landfill facility, and continue with the ACM process.

3. RISK ASSESSMENT

Vinyl Chloride:

Vinyl chloride is a synthetic chemical obtained either by hydrochlorination of acetylene or by halogenation of ethylene (ILO, 1983; Budavari, 1989). Under normal conditions of temperature and pressure, vinyl chloride is a colorless gas with mild ethereal odor. It is usually handled under pressure as a colorless liquid. Vinyl chloride is used for the production of vinyl chloride homo-polymer and co-polymer resins; these have many applications. It was formerly considered for use as an anesthetic agent, but was finally abandoned for this purpose because of cardiac arrhythmias during anesthesia. It has also been used as a refrigerant, an extraction solvent, a propellant, and for the production of methyl chloroform (ECETOC, 1988). The 2L Standard is 0.015 micrograms per liter (μg/L) for vinyl chloride in drinking water.

Vinyl chloride has been detected above the 2L Standard in compliance wells MW-1, MW-1A, MW-5, MW-5S, MW-6, and MW-8A and piezometers P-31, P-33 during one or more sampling events since September 1994. The release of vinyl chloride is primarily centered at, and within the vicinity of, MW-5.

Based on the hydraulic conductivities of the site and the sampling results of the NES, the release of vinyl chloride may reach the Jerry's Creek. However, the topographically low area along Jerry's Creek acts as a local hydraulic divide for the uppermost prevalent aquifer except during drought conditions when groundwater levels have lowered and the creek at times has been dry.

Based on the receptor survey results which were obtained by S&ME during completion of the NES, there are no identified drinking water wells located downgradient of the landfill facility. Therefore, the level of risk to human health is expected to be low. The detailed results of the receptor survey are presented in the landfill's *Nature and Extent Study*, S&ME Inc. June 2008. The primary risk of impact from this release, if any, will be aquatic life in the receiving creek. Based on the historical surface water quality monitoring results, vinyl chloride has never been detected above the method detection limit in any surface water samples collected from any surface water sampling point. Therefore, the risk posed to human health and the environment from the release of vinyl chloride at the landfill is expected to be low.

Benzene:

Benzene is highly flammable and is formed from both natural processes and human activities. Benzene is widely used in the United States; it ranks in the top 20 chemicals for production volume. Some industries use benzene to make other chemicals which are used to make plastics, resins, and nylon and synthetic fibers. Benzene is also used to make some types of rubbers, lubricants, dyes, detergents, drugs, and pesticides. Natural sources of benzene include volcanoes and forest fires. Benzene is also a natural part of crude oil, gasoline, and cigarette smoke.

While benzene has been detected in groundwater monitoring wells MW-1A, MW-2A, MW-5, MW-6, MW-7A, MW-8, and MW-8A, and piezometers P-4 and P-31 at reported concentrations exceeding the 2L Standard of 1.0 μg/L, the detections of benzene at the landfill have primarily centered around compliance monitoring well MW-5. The detection in P-4 may indicate a release from the northern adjacent closed landfill, since the closed landfill is located between the other wells with 2L Standard exceedances and P-4.

Based on the receptor survey results, there are no identified drinking water wells located downgradient of the landfill and the level of risk to human health is expected to be low. The primary risk of impact from this release, if any, will be aquatic life in the receiving creek. Based on the historical surface water quality monitoring results, benzene has never been detected above the method detection limit in any surface water sample collected from any surface water sampling point. Therefore, the risk posed to human health and the environment from the release of the low levels of benzene observed at the landfill is expected to be low.

Cis-1,2-Dichloroethene:

Cis-1,2-dichloroethylene, is a highly flammable, colorless liquid with a sharp, harsh odor. It is used to produce solvents and in chemical mixtures.

Cis-1,2-dichloroethene evaporates rapidly into air. In the air, it takes about 5-12 days for half of it to break down. Most cis-1,2-dichloroethene in the soil surface or bodies of water will evaporate into air. Cis-1,2-dichloroethene can travel through soil or dissolve in water in the soil and therefore it can contaminate groundwater. In groundwater, it takes about 13-48 weeks to break down. There is a slight chance that cis-1,2-dichloroethene will break down into vinyl chloride, a different chemical which is believed to be more toxic than cis-1,2-dichloroethene.

The compound cis-1,2-dichloroethene has been detected above the 2L Standard of 70 μg/L in monitoring wells MW-1A, MW-5 and piezometer P-31. However, since January 2003, cis-1,2-dichloroethene has only been detected in groundwater monitoring well MW-5 and piezometer P-31 at concentrations which exceeded the 2L Standard for this constituent. Cis-1,2-dichloroethene has been detected at low level concentrations sporadically in monitoring well MW-1A, but at levels significantly less than the 2L Standard.

Throughout the surface water monitoring history at the Edgecombe County Landfill, cis-1,2-dichloroethene has only been detected twice in surface water quality monitoring results. The first detection, 0.38 μg/L, was from the downstream sample collected during the January 2007 surface water monitoring event. The second detection at a reported concentration of 0.68 μg/L was also from the downstream sample collected during the January 2008 surface water monitoring event. While these reported concentrations are low and close to the method detection limit, no15A NCAC 2B surface water standard has been established for cis1,2-dichloroethene. EPA has established a general drinking water standard of 70 μg/L for short term exposures to cis-1,2-dichloroethene which is equal to the 2L Standard.

Based on the receptor survey results which were obtained by S&ME during completion of the NES, there are no identified drinking water wells located downgradient of the landfill. Therefore, the level of risk to human health is expected to be low.

The primary risk of impact from this release, if any, will be aquatic life in the receiving creek. Because the levels of cis-1,2-dichloroethene are low and close to the detection limit and are below the EPA drinking water standard, the level of risk posed to aquatic life in the creek from the release of cis-1,2-dichloroethene is expected to be low.

Trichloroethene:

Trichloroethene is a colorless liquid with a characteristic, slightly sweet odor. It is used as a solvent in a variety of applications. A major use of trichloroethene is in metal degreasing; other significant uses are in textile cleaning, solvent extraction processes and as a carrier solvent. It is no longer used as a grain fumigant and is now only occasionally used in anesthesia. For practical use, trichloroethene requires the addition of stabilizers (up to 2%). Trichloroethene is degraded in biological and abiotic systems.

Trichloroethene has been detected above the 2L Standard of 2.8 μg/L in groundwater monitoring wells MW-1A, and MW-5, and piezometer P-31. The detections of trichloroethene at the landfill have been isolated to samples collected from MW-5 and P-31 since the October 1996 sampling event.

Trichloroethene has been present in monitoring well MW-5 since the first sampling event in September 1994. However, the reported concentrations in MW-5 have shown a dramatic decreasing trend in concentration over time. Therefore, the release from the landfill appears to have been a slug type release. The trend of decreasing concentrations of this constituent in groundwater samples from MW-5 and the current downward trend in concentrations of trichloroethene in the vicinity of MW-5 is expected to continue to decrease.

Based on the NES receptor survey results, there are no identified drinking water wells located downgradient of the landfill and the level of risk to human health is expected to be low. The primary risk of impact from this release, if any, will be aquatic life in the receiving creek. Based on the historical surface water quality monitoring results, trichloroethene has never been detected above the method detection limit in any surface water samples collected from any surface water sampling point. Therefore, the risk posed to human health and the environment from the release of the low levels of trichloroethene observed at the Edgecombe County Landfill is expected to be low.

1,4-Dichlorobenzene:

1,4-Dichlorobenzene is a colorless to white solid with a strong and pungent odor. When exposed to air, it slowly changes from a solid to a vapor. 1,4-Dichlorobenzene often enters the environment when it is used in mothballs and in toilet-deodorizer blocks. 1,4-Dichlorobenzene can bind to soil and sediment. 1,4-Dichlorobenzene in soil usually is not easily broken down by soil organisms. Evidence suggests that plants and fish absorb dichlorobenzenes.

1,4-Dichlorobenzene as been detected above the 2L Standard of 1.4 µg/L in groundwater monitoring wells MW-5 and MW-7A. Since monitoring began for MW-7A there has been only one detection of 1,4-dichlorobenzene, in January 2008. However, detections in MW-5 have sporadically been above the 2L Standard since monitoring began in September 1994. As with the other constituents of concern, the release of 1,4-dichlorobenzene is primarily centered at, and within the vicinity of, MW-5.

Since there are no identified drinking water wells located downgradient of the landfill, as with the other constituents of concern, the level of risk to human health is expected to be low. Additionally, based on the historical surface water quality monitoring results, 1,4-dichlorobenzene has never been detected above the method detection limit in any surface water sample collected from any surface water sampling point. Therefore, the risk posed to the aquatic life in the receiving creek from the release of 1,4-dichlorobenzene is expected to be low.

Cobalt:

In June of 2008, S&ME completed an Alternate Source Demonstration (ASD) for metals at the Edgecombe County Landfill. The results of the ASD showed that the concentrations of cobalt detected in the background soil samples do not support influence to groundwater quality from the natural occurrence of the metal cobalt because, while cobalt was detected in the in-situ soils at the facility, the naturally occurring levels of cobalt in the soil are not sufficient to attribute the levels of cobalt detected in the groundwater samples from monitoring well MW-5 solely to its natural occurrence in the overlying soils. Therefore, cobalt is the remaining inorganic constituent of concern at the landfill.

Historical groundwater monitoring results indicate that cobalt has only been detected in monitor well MW-5 at levels exceeding the GWPST of 70 µg/L. The reported concentrations of cobalt in groundwater samples collected from MW-5 are close to this groundwater protection standard.

Cobalt is used in alloys, magnets, in the production of tungsten carbide, in catalysts, pigments and enamels.

Cobalt and its salts are relatively non-toxic by ingestion. Most cases of cobalt toxicity relate to occupational skin contact or inhalation. Cobalt is a topical irritant and a well-recognized cause of occupational contact dermatitis.

Due to the lack of a complete pathway for human ingestion of cobalt at the landfill, coupled with the fact that there are no identified drinking water wells located downgradient of the landfill, the level of risk to human health is expected to be low.

The primary risk of impact from the release of cobalt, if any, will be aquatic life in the receiving creek. Based on the historical surface water quality monitoring results, cobalt has never been detected in any surface water sample from any surface water monitoring point above the 15A NCAC 2B Surface Water Standard (2B Standard) with the exception of the sample collected from "Ditch 2" during the January 2002 surface water monitoring event. The reported concentration from this event, 0.21 µg/L, is the single detection of cobalt above the 2B Standard set at 0.065 μg/L. Since cobalt has not been detected above the 2B Standard since 2002, it is unlikely that this single detection of cobalt in a surface water sample represents a release of cobalt by the landfill. Therefore, the risk posed to aquatic life in the receiving creek form cobalt is expected to be low. However, continued monitoring of cobalt in the receiving creek should continue. If, at some point in the future, cobalt is detected at reported concentrations above the 2B Standard on a regular basis, and at relatively higher concentrations downgradient than upgradient of the landfill, the impacts to surface water quality may have to be addressed through one of the potential corrective measures discussed in **Section 4.0** below.

4. POTENTIAL REMEDIAL ACTIONS OF GROUNDWATER CORRECTIVE MEASURES

The following corrective measures were examined so as to present possible feasible solutions to Edgecombe County, the governing body complying with the conditions of the NCDENR DWM Solid Waste Permit No. 33-01 and to those potentially effected by the off-site contaminant migration. Each of the corrective measures listed here are considered feasible; however, only a select few will have the greatest effect on the potential contaminant migration given the patterns of the sampling analysis, and the environmental conditions of the impacted area. The selection of a remedy is controlled by the geologic and hydrogeologic conditions at the site, and the risks associated with the release. More aggressive remedial alternatives tend to have a higher capital cost for implementation. The aggressiveness of the selected remedy is usually controlled by the level of risk(s) to downgradient receptors from the associated release. If there is a high level of risk to receptors, the situation may dictate implementation of a more aggressive remedial technology due to the immediate need to reduce risk to the receptors. Conversely, sites with low risk to downgradient receptors may not require such aggressive technology since contaminant levels may more closely approximate regulatory clean-up goals and time budgets would allow for remediation over a longer period.

The goal of the corrective measures process is to restore groundwater quality to the level of the standard or as closely there to as is economically and technologically feasible. The NCDENR DWM indicates that remediation will be complete when concentrations of the constituents of concern are less than the 2L Standard for three consecutive years when measured in all points within the plume that lie at and beyond the groundwater compliance monitoring well network. Therefore, the objective of corrective action for this ACM is to reduce the concentrations of the constituents of concern to levels below the 2L Standards within the plume of contamination at points lying at and beyond the compliance well network. The following **Table 1** contains methods that were selected for evaluation as an appropriate remedy for corrective action at the landfill. Most of these are listed in the *Examples of Approved Groundwater Corrective Measures for Solid Waste Management Facilities* in the memo issued by State of North Carolina Department of Environment and Natural Resources, Division of Waste Management, Solid Waste Section, March 2007. In **Table 2**, each method is either retained (R) or eliminated (E) due to limiting factors in the potential performance at the landfill. Those retained will be discussed in further detail in the following sections.

Table 1
Preliminary Technology Screening
General Response Actions – Preliminary Technologies Screening

GROUNDWATER REMEDIATION		
Remedial Action	**General Response Action Options**	**Preliminary Technologies**
No Active Remediation	No Further Action	No Further Action
	Institutional Controls	Monitored Natural Attenuation
		Access Restrictions
		Deed Restrictions
Removal	Groundwater Collection	Pumping Wells/Hydraulic Barrier
		Interceptor Trenches
	Gas Extraction	Aggressive Gas Extraction
Treatment	*In-Situ* Treatment	Bio-Remediation / Volatilization
		Chemical Oxidation
		Chemical Fixation
	On-Site Treatment	Physical: Air Stripping, Carbon Adsorption, Evaporation, Filtration, Ion Exchange, Reverse Osmosis
		Chemical: Neutralization, Physical/Chemical Separation, Solvent Extraction, UV/Chemical Oxidation, Wet Air Oxidation
		Biological: Constructed Wetlands, Activated Sludge, Aeration Tank, Fixed Film Biological Reactor
	Off-Site Treatment	Industrial Treatment Facility
Disposition	*In-Situ* Isolation	Surface Cap / Grade: Limit Stormwater or Surface Water Into Source Area
		Barrier / Containment Wall
	On-Site Disposal	Discharge to Surface Water
		Recharge to Groundwater
	Off-Site Disposal	POTW Discharge

Table 2
Preliminary Technical Screening of Groundwater Remedial Technologies

Remedial Action	General Response Action Options	Preliminary Technologies	Eliminated (E) Retained (R)	Rationale
No Active Remediation	No Further Action	No Further Action	E	Required benchmark option
	Institutional Controls	Monitored Natural Attenuation	R	Potentially feasible method for limiting exposure once the source of the dissolved plume is stabilized
		Access Restrictions	R	Potentially feasible method for limiting exposure
		Deed Restrictions	R	Potentially feasible method for limiting future exposure
Removal	Groundwater Collection	Pumping Wells/Hydraulic Barrier	R	Technology is feasible and could be employed to maintain hydraulic control or achieve mass removal.
		Interceptor Trenches	R	Technology is feasible and could be employed to maintain hydraulic control or achieve mass removal.
	Gas Extraction	Volatilization	R	Viable alternative for treatment of VOCs, without effecting metals
Treatment	*In-Situ* Treatment	Bio-Remediation / Volatilization	E	Viable alternative for treatment of VOCs, not viable for metals
		Chemical Oxidation	E	Viable alternative for treatment of VOCs, not viable for metals, may require many periodic applications
		Chemical Fixation	E	Viable alternative for treatment of metals, not viable for VOCs, may require many periodic applications

Table 2 (continued)
Preliminary Technical Screening of Groundwater Remedial Technologies

Treatment (cont.)	On-Site Treatment	<u>Physical:</u> Air Stripping	R	Feasible method for treating volatile and semi-volatile fractions of contaminant stream
		Carbon Adsorption	R	Not applicable as a stand-alone treatment technology but potential use as secondary or tertiary treatment
		Evaporation	E	Not retained as technology is normally used to remove excess water from highly concentrated wastes
		Filtration	R	Potentially feasible as pre- or post-treatment technology
		Ion Exchange	R	Potential remedial technology for treating dissolved metals in recovered groundwater
		Reverse Osmosis	R	Potential remedial technology for treating dissolved metals in recovered groundwater
		<u>Chemical:</u> Neutralization	R	Not required for treatment of groundwater, but may be used in conjunction with other treatment options
		Physical/Chemical Separation	R	May be used in conjunction with neutralization to settle out metal hydroxides
		Solvent Extraction	E	Primarily used for treatment of process water where chemical recovery warranted
		UV/Chemical Oxidation	E	Not viable due to low levels of VOCs & high operating costs
		Wet Air Oxidation	E	Not a viable remedial alternative due to associated costs and required organics levels, typically 5% - 10%

Table 2 (continued)
Preliminary Technical Screening of Groundwater Remedial Technologies

Treatment (cont.)	On-Site Treatment (cont.)	Biological: Constructed Wetlands	R	Viable for treatment of COCs
		Activated Sludge	E	Due to variable nature of COCs present, these processes are not viable
		Aeration Tank	E	
		Fixed Film Biological Reactor	E	
	Off-Site Treatment	Industrial Treatment Facility	E	Hauling and disposal fees are cost prohibitive
Disposition	In-Situ Isolation	Surface Cap / Grade: No Stormwater or Surface Water Into Source Area	R	Viable as drying out of shallow waste source will minimize contaminant migration
		Barrier / Containment Wall	R	Viable as drying out of shallow waste source will minimize contaminant migration
	On-Site Disposal	Discharge to Surface Water	R	Potential discharge option for treated water
		Recharge to Groundwater	E	Not viable, as drying out of waste source area is desired
	Off-Site Disposal	POTW Discharge	R	Potential disposal option but must make connection several miles away

The following is a list of remedies that were retained:

- Institutional Controls – Monitored Natural Attenuation, Access Restrictions, and Deed Restrictions
- Groundwater Collection –Pumping Wells/Hydraulic Barrier and Interceptor Trenches
- Gas Extraction – Volatilization
- On-Site Treatment – Physical: Air Stripping, Carbon Adsorption, Filtration, Ion Exchange, Reverse Osmosis
    - Chemical: Neutralization, Physical/Chemical Separation
    - Biological: Constructed Wetlands
- In-Situ Isolation – Surface Cap / Grade and Barrier / Containment Wall
- Off-Site Disposal – POTW Discharge
- On-Site Disposal – Discharge to Surface Water

The site already has access and deed restrictions. The physical and chemical on-site treatment remedies could be combined into on-site water treatment system. The following options are discussed in further detail below:

- Option 1 – Monitored Natural Attenuation;
- Option 2 – Groundwater Collection with Off-Site Disposal or On-Site Treatment and On-Site Disposal;
- Option 3 – Gas Extraction; and
- Option 4 – In-Situ Isolation.

4.1 Option 1 – Monitored Natural Attenuation

4.1.1 Method Description

Natural attenuation is the reduction in mass or concentration of a chemical in groundwater over time or distance from the source of contamination due to naturally occurring physical, chemical, and biological processes. These naturally occurring physical, chemical, and biological processes include: dispersion, dilution, sorption, volatilization, biodegradation/biotransformation, and abiotic degradation/transformation.

There are two types of mechanisms of natural attenuation; non-destructive and destructive mechanisms. Non-destructive mechanisms result in reduction in groundwater concentrations with no mass loss of contaminants from the system. Non-destructive mechanisms include dispersion, dilution from recharge, sorption, and volatilization. In the sorption process contaminant mass is transferred to aquifer solids. During volatilization contaminant mass is transferred to the surrounding atmosphere.

Destructive mechanisms of natural attenuation results in mass loss of contaminants from the system. Destructive mechanisms include aerobic biodegradation, anaerobic biodegradation, cometabolism, abiotic oxidation/reduction reactions, and hydrolysis. The affects of the natural attenuation process can be seen over increased distance from a continuous contaminant source in a tapered linear relationship when compared with source concentrations. With increasing distance from a slug release contaminant source, the relationship between attenuation and contaminant concentrations will be represented by a bell curve plot of groundwater quality data over time throughout the natural attenuation process. For the Edgecombe County Landfill, it has not yet been determined if the contaminant plume is still in a growth phase, stable phase, or if the plume has already reached its peak and is now a shrinking plume. Plume behavior at the landfill would be determined during the Monitored Natural Attenuation (MNA) process.

MNA is considered as an appropriate remedy for corrective measures at a landfill if the site meets the following criteria as defined under 15A NCAC 2L .0106(l):

1. All sources of contamination and free product have been removed or controlled;
2. The contaminant has the capacity to degrade or attenuate under the site-specific conditions;
3. The time and direction of contaminant travel can be predicted with reasonable certainty;
4. Contaminant migration will not result in any violation of applicable groundwater standards at any existing or foreseeable receptor;
5. Contaminants have not and will not migrate onto adjacent properties, or that:
   (A) such properties are served by an existing public water supply system dependent on surface waters or hydraulically isolated groundwater, or
   (B) the owners of such properties have consented in writing to the request;
6. If the contaminant plume is expected to intercept surface waters, the groundwater discharge will not possess contaminant concentrations that would result in violations of standards for surface waters contained in 15A NCAC 2B .0200;
7. The person making the request will put in place a groundwater monitoring program sufficient to track the degradation and attenuation of contaminants and contaminant byproducts within and downgradient of the plume and to detect contaminants and contaminant byproducts prior to their reaching any existing or foreseeable receptor at least one year's time of travel upgradient of the receptor and no greater than the distance the groundwater at the contaminated site is predicted to travel in five years;
8. All necessary access agreements needed to monitor groundwater quality have been or can be obtained;
9. Public notice of the request has been provided; and
10. The proposed corrective action plan would be consistent with all other environmental laws.

Biodegradation will be the primary reduction process of VOCs in the landfill mass during the natural attenuation process. Biodegradation involves biologically mediated oxidation/reduction reactions and is fundamentally an electron transfer process. Electrons are transferred from more reduced compounds to more oxidized compounds. Energy released is used by microbes to sustain metabolism and growth. Redox chemistry is a good analogy of this process in that electron donors are what microbes "eat" and electron acceptors are what microbes "breath" (Barden & Wiedemeier 1997). Electron donors include natural organic carbon, fuel hydrocarbons, and most importantly for this case, landfill leachate constituents.

The VOC constituents of concern at the landfill include the organic parameters: vinyl chloride, benzene, cis-1,2-dichloroethene, trichloroethene, and 1,4-dichlorobenzene, as well as the inorganic constituent cobalt. The metal, cobalt, may attenuate through dispersion and dilution in the aquifer. Research has shown that chlorinated solvent, trichloroethene, biodegrades via halorespiration (Barden & Wiedemeier 1997). Trichloroethene has also been shown to degrade through cometabolism. Finally, vinyl chloride, an anthropogenic Cl-ethene, will biodegrade through aerobic respiration and iron (III) reduction. Based on the years of groundwater monitoring analytical data coupled with the various studies throughout the groundwater monitoring history of the landfill including the previously discussed NES, the primary substrate at the landfill should contain a sufficient quantity of anthropogenic organic carbon to support biodegradation of the chlorinated solvents of concern. In addition, there is likely native organic carbon in trace amounts which will further enhance biodegradation rates of these constituents. However, exact analysis of existing native organic carbon has not been studied to date. The dominant thermal electron-accepting process through which biodegradation takes place is:

Aerobic Respiration	Dentrification	Iron (III) Reduction	Sulfate Reduction	Methanogenesis

Time --►

◄-- **Distance From Source**

(After: Bower and McCarty, 1984)

The geochemical content of the uppermost monitored aquifer will evolve over time due to the biodegradation process. Based on the above equation, with increased time, a decrease in electron acceptors such as dissolved oxygen, nitrate, FE(III), SO^{2-}_4 and CO_2 will occur close to the source as a result of the metabolic processes intrinsic to the hydrogeologic regime at the site. Conversely there will be an increase in degradation/transformation products including dissolved iron, methane, ethene, and chloride. If additional lines of evidence for natural attenuation are needed, microbiological indicators can be analyzed and included in the study if warranted. The effectiveness and magnitude of the natural attenuation process can be demonstrated through inclusion of these constituents during the routine groundwater sampling and subsequent analytical analysis. Monitoring these indicators as well as noting reductions in the concentrations of the landfill constituents of concern over time will be essential for mapping and gauging a successful natural attenuation process over time.

MNA can result in complete mineralization of VOC contaminants to innocuous products. Although considered a "passive" technique, it allows for continuing use of infrastructure and can be very cost effective.

An evaluation of the risks posed to human health and the environment at the landfill is included in this report. Based on the risk evaluation it may be concluded that MNA would be an appropriate remedial measure for the landfill.

This process would involve sampling the appropriate property boundary groundwater monitoring wells for the constituents found over the 2L Standard. After an appropriate amount of samples have been taken, assumptions may be drawn concerning the constituent magnitude concentration trend (increasing, decreasing, or static) in order to reevaluate the dispersion and natural attenuation process effectiveness. The objectives for a monitored natural attenuation groundwater remediation program include the following:

- Demonstrate that natural attenuation is occurring
- Be protective of human health and the environment
- Monitor natural attenuation and environmental impact; and
- Restore groundwater at the edges of the plume to below the 2L Standard and GWPST

4.1.2 Performance and Reliability

MNA is a proven remedial alternative and can successfully restore groundwater quality and return monitored constituents to within 2L Standard levels. MNA has been used at many different types of sites to treat both impacted groundwater and soils. MNA is an adequate stand alone remedy in cases where there is no identified risk to human health or the environment, and/or when proactive remediation is not likely to be more effective than MNA at restoring groundwater quality.

MNA performance differs at every site and is dependant on the individual site conditions. Therefore, performance of MNA is typically determined by long term monitoring for the monitored contaminant parameters, daughter products if any, and other indicators of attenuation such as electron acceptors (oxygen, sulfate, nitrate, and ferrous iron) and waste products (ethene, methane, chloride, carbon dioxide, etc.).

4.1.3 Associated Receptor Impacts

There are no major remediation-related impacts associated with MNA, since MNA results in the destruction of the VOC contamination and dilution and dispersion of inorganic contaminants. Minor impacts would include the generation of contaminated purge water, which would have to be properly disposed.

4.1.4 Remediation Timeframe

The timeframe for achieving objectives should be reasonable compared to other alternatives. The existing and historical data can be used as a predictor of future result. Based on the historical groundwater data, it is reasonable to believe that the 2L Standards and GWPSTs can reasonably be obtained in 15+ years based on case study literature. It is believed that MNA has already been occurring and is evidenced by the daughter products such as vinyl chloride already present in the compliance and NES groundwater monitoring wells.

4.1.5 Implementation Requirements

In order to implement MNA at the landfill, a Performance Monitoring (PM) program designed to address the higher level of uncertainty regarding the mass contaminants and predictive analyses will be required. Per the EPA Office of Solid Waste and Emergency Response (OSWER) Directive (1999), performance monitoring to evaluate the remedy effectiveness and to ensure protection of human health and the environment is an important element of all response actions. The monitoring program will likely be designed to incorporate the following:

Demonstrate that natural attenuation is occurring according to expectations;

- Detect changes in environmental conditions that may reduce the efficacy of any of the natural attenuation processes;
- Identify potentially toxic and/or mobile transformation products;
- Verify that the plume(s) is not expanding
- Verify no unacceptable impact to downgradient receptors
- Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy;
- Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors; and
- Verify attainment of remediation objectives.

Edgecombe County would implement the PM program through a Corrective Action Plan which would be prepared and submitted to DENR upon approval of the ACM. The existing monitoring network plus the NES wells would be utilized for the PM program. Monitoring wells MW-3B, MW-4, and MW-9, the upgradient wells, would allow determination of geochemical conditions in the groundwater prior to entering the source area. Monitoring well MW-5 is located in the plume and will be utilized to collect data for bioremediation rate calculations. Additional wells may be required along the downgradient facility boundary to define the edge of the plume and act as sentinel wells. These wells would be monitored and evaluated to determine if bioremediation is working as well as to determine if triggers have been exceeded. A revised Water Quality Monitoring Plan (WQMP) would be prepared as part of the Corrective Action Plan.

4.1.6 Institutional Requirements

The Waste Division at NCDENR will require modification to the operating permit for the landfill.

4.2 Option 2 – Groundwater Collection

Option 2 will consist of groundwater collection with the following sub options:

- Option 2A – Off-Site Disposal
- Option 2B – On-Site Water Treatment System and On-Site Disposal
- Option 2C – Constructed Wetland and On-Site Disposal

4.2.1 Groundwater Collection

4.2.1.1 Method Description

Conventional groundwater collection is used for cleanup of both organics and inorganics in groundwater. When groundwater collection is selected, a decision needs to be made about the use of wells or trenches. If the hydraulic conductivity is sufficiently high to allow flow to wells, then wells are recommended. For low permeability material, trenches may be required. Wells can be categorized as extraction, injection, or a combination. Injection wells reduce cleanup time required by flushing chemicals into extraction wells. Design and management decisions concerning extraction wells include whether to use continuous pumping, pulsed pumping, or pumping combined with containment. While continuous pumping maintains an inward hydraulic gradient, pulsed pumping allows maximum concentrations to be pumped and requires pumping less volume of water.

Groundwater collection systems may be used for plume containment and plume recovery for above ground treatment. Groundwater pumping systems utilize the principle that groundwater flows in response to a hydraulic gradient, i.e., a drop in hydraulic pressure created by the combined effects of elevation, fluid density, and gravity. The pumped contaminated groundwater that is withdrawn from an aquifer can be treated by various methods, depending on the type(s) of contamination.

Groundwater collection systems are expensive to install and relatively expensive to operate. They also require regular maintenance and performance sampling. Groundwater collection is a viable option for landfills; however, the expense and the uncertain timeframe for achieving remedial goals often necessitate the use of a pilot study to better predict the effectiveness of a pump and treat system for a particular site.

4.2.1.2 Performance and Reliability

Groundwater collection technology is relatively simple to design and operate, and uses standard equipment. It can be implemented quickly and is compatible with adjunct treatment methods as will be later discussed.

The recovery well network should be designed to capture water from the center (high concentration area) of the plume for rapid mass removal and from the leading edge of the plume to minimize plume spread. Trenching would be designed to capture water from the leading edge of the plume to minimize plume spread.

Groundwater recovery systems have several important limitations, including high energy costs for pumping and moving large volumes of water, indiscriminate removal of all groundwater components, and potential impacts on groundwater resources. Additionally, the performance of groundwater collection to remediate an aquifer containing VOCs and inorganics is moderate to poor if the goals of the remediation are to reduce the contaminant levels in the already impacted portion of the aquifer. The extraction process for the contaminants becomes diffusion controlled (residual to dissolved) once saturated components of the dissolved phase contamination have been removed from the aquifer.

4.2.1.3 Associated Receptor Impacts

A groundwater collection system risk to other environmental receptors is directly associated with which treatment or disposal option is chosen. These impacts are discussed further within each option description.

4.2.1.4 Remediation Timeframe

A groundwater collection system remediation timeframe is directly associated with which treatment or disposal option is chosen. The remediation timeframe is discussed further within each option description.

4.2.1.5 Implementation Requirements

In order to implement a groundwater collection system a number of extraction wells or trenches will have to be installed. For the use of wells, the fundamental design components include the number of extraction wells, placement of the extraction wells, pumping rates, and managing the extracted groundwater at the surface. For the use of trenches, the fundamental design components include the number of trenches and size, placement of the trenches, flow rates, and managing the groundwater from the trenches to the surface. In order to assist in designing either type of system, it is often useful to construct an analytical groundwater flow model or site numerical flow model to optimize the number, location, and pumping rate of the extraction wells.

The requirements of the treatment of extracted groundwater is directly associated with which treatment or disposal option is chosen. These impacts are discussed further within each option description.

4.2.1.6 Institutional Controls and Requirements

Institutional controls and requirements of a groundwater collection system may require several permits for operation depending on which treatment or disposal option is chosen. These requirements are discussed further within each option description.

4.2.2 Option 2A – Off-Site Disposal

4.2.2.1 Method Description

Off-site treatment is a simple method because the groundwater would be removed from the site and disposed/treated properly by a third party. The groundwater would be placed in a closed container for storage prior to removal off-site.

4.2.2.2 Performance and Reliability

Performance and reliability would rest on the ability to transport the contaminated groundwater off-site.

4.2.2.3 Associated Receptor Impacts

A disposal off-site system should not present a significant risk to other environmental receptors. This is due to the fact that for the case in point, treatment of the extracted constituent laden groundwater would not take place on-site. However, potential leaks in the system are possible and maintenance is necessary.

4.2.2.4 Remediation Timeframe

Remediation timeframe would be contingent on the chosen method for groundwater collection. It would also be affected by whether the source of contamination was a slug type release or is a continual source. If there is a continual source, remediation of the site could take a much longer time had there only been a slug of contamination. That is a factor that may or may not be able to be determined prior to implementation.

4.2.2.5 Implementation Requirements

In order to implement an off-site disposal system, a groundwater storage containment must be designed in order to contain the volume and rate of groundwater to be removed. Secondary containment could be constructed around the container if necessary. Coordination with a permitted transporter and disposal/treatment facility would be required to handle the volume and rate of groundwater to be removed.

4.2.2.6 Institutional Controls and Requirements

Transportation and disposal/treatment would have to be conducted by a permitted subcontractor. Additional permitting may be required for the disposal/treatment facility.

4.2.3 Option 2B – On-Site Water Treatment System

4.2.3.1 Method Description

The pumped contaminated groundwater that is withdrawn from an aquifer can be treated by various methods, depending on the type(s) of contamination. Treatment methods may include one or more of the following: (1) physical processes, such as air stripping, carbon adsorption, filtration, ion exchange, reverse osmosis; (2) chemical processes, such as neutralization, or physical/chemical separation; or (3) biological processes, which will be discussed in **Section 4.2.4**.

Groundwater treatment systems are expensive to install and relatively expensive to operate. They also require regular maintenance and sampling. Pump and treat is a viable option for landfills; however, the expense and the uncertain timeframe for achieving remedial goals often necessitate the use of a pilot study to better predict the effectiveness of a pump and treat system for a particular site.

4.2.3.2 Performance and Reliability

On-site treatment technology is relatively simple to design and operate, uses standard equipment, and can treat all types of dissolved contamination. It allows flexibility in meeting various cleanup goals (e.g., mass reduction versus plume spread). It can be implemented quickly and is compatible with adjunct technologies (e.g., vacuum extraction or in-situ air stripping) for overall cost effectiveness.

On-site treatment has several important limitations, including generation of substantial amounts of secondary waste water, energy costs for equipment operation, potential impacts on groundwater resources, and slow progress toward terminal regulatory goals due to recovery limitations.

The chemical characteristics of the contaminants to be removed are critical to the success or failure of treatment. The solubility and partitioning coefficients (Kd and/or Kow) of the contaminants for soil and water must be considered to assess the feasibility of such a system. On-site treatment is most effective on compounds with low partitioning coefficients and high solubility (i.e., most chlorinated hydrocarbons).

4.2.3.3 Associated Receptor Impacts

An on-site treatment system should not present a significant risk to other environmental receptors. This is due to the fact that treatment will likely occur in a closed system. However, potential leaks in the system are possible. Regular sampling would be required to assure water met standards for discharge to the surface water.

4.2.3.4 Remediation Timeframe

The remediation timeframe for an on-site treatment system would depend on the chosen groundwater recovery and treatment process. However, it is likely the option chosen will result in a prompt treatment for discharge. It would also be affected by whether the source of contamination was a slug type release or is a continual source. If there is a continual source, remediation of the site could take a much longer time had there only been a slug of contamination. That is a factor that may or may not be able to be determined prior to implementation.

4.2.3.5 Implementation Requirements

In order to implement an on-site treatment system, a system would need to be designed and purchased that would treat the contaminants of concern. Pumping, flow, and volume rates would need to be considered in the design process. Regular sampling of discharge water would need to occur as well as maintenance and equipment checks.

4.2.3.6 Institutional Controls and Requirements

Implementation of an on-site treatment system may require several permits for operation. Discharge of impacted groundwater to a sewer system may require a POTW permit in lieu of the discharge permit. Treated groundwater would require a discharge permit from the NCDENR DWM and likely a National Pollutant Discharge Elimination System (NPDES) permit to dispose of constituent impacted groundwater which is diverted and subsequently captured for treatment, and the operating permit for the landfill would require modification by the NCDENR DWM.

4.2.4 Option 2C – Constructed Wetlands

4.2.4.1 Method Description

The constructed wetlands-based treatment technology uses natural geochemical and biological processes inherent in an artificial wetland ecosystem to accumulate and remove metals and VOCs from influent waters. The process can use a filtration or degradation process. The technology incorporates principal components of wetland ecosystems; including organic soils, microbial fauna, algae, and vascular plants.

Biotic and abiotic activity within the wetland is responsible for the remediation process. Influent water flows through and beneath the gravel surface of a gravel-based wetland.

The anaerobic cell uses plants in concert with natural microbes to degrade the contaminant. The aerobic, also known as the reciprocating cell, further improves water quality through continued exposure to the plants and the movement of water between cell compartments and volatilization of those components.

Influent waters with high metal concentrations and low pH flow through the aerobic and anaerobic zones of the wetland ecosystem. Metals are removed through ion exchange, adsorption, absorption, and precipitation with geochemical and microbial oxidation and reduction. Ion exchange occurs as metals in the water contact humic or other organic substances in the wetland. Wetlands constructed for this purpose often have little or no soil, but instead they have straw, manure or compost. Oxidation and reduction reactions catalyzed by bacteria that occur in the aerobic and anaerobic zones, respectively, play a major role in precipitating metals as hydroxides and sulfides. Precipitated and adsorbed metals settle in quiescent ponds or are filtered out as water percolates through the medium or the plants.

4.2.4.2 Performance and Reliability

A pilot study would be implemented in order to further assess the performance and reliability of a constructed wetland to remediate the contaminants of concern in the groundwater. Once a pilot study is completed an estimated cell area can be determined. The performance will also be directly linked to the growth, maintenance, and maturity levels of the constructed wetland.

The chemical characteristics of the contaminants to be removed are critical to the success of the constructed wetlands. Concentrations of contaminants determine the survivability and maturity rate of biological agents within the cells.

Seasons present a limitation on the performance and reliability of constructed wetlands. Freezing affects pumping and flow rates as well as plant growth and survival. These factors should be studied and taken into consideration during the pilot study.

4.2.4.3 Associated Receptor Impacts

Constructed wetlands should not present a significant risk to other environmental receptors with the exception of uptake from plants and introduction to herbivorous wildlife. This is due to the fact that certain contaminants are taken up by root systems and collected in the plants. If the plants are exposed to animal consumption the contaminants may be transferred to the environment.

4.2.4.4 Remediation Timeframe

The remediation timeframe for a constructed wetland system will depend on the groundwater recovery rates and the acreage of the treatment cell, maturity of biological factors within the wetland, and concentration of contaminants of concern. The more acreage available for constructed wetlands, the higher the volume of groundwater that can be pumped into the system and treated, speeding up the treatment time. If the biological factors within the wetland mature well and thrive with the introduction of contaminated groundwater treatment time may decrease. If concentrations exceed the threshold of wetland sustainability by increasing factors such as pH, and survival of biological factors is minimal, treatment time may increase.

Overall, constructed wetlands are not an immediate treatment system, however, they are usually affective after a prolonged time period. Treatment time is longer than some other alternatives.

4.2.4.5 Implementation Requirements

There are three major components that characterize a wetland; soils, hydrology, and vegetation. Through the pilot study each of these three components must be studied to design an effective system.

In order to implement a constructed wetland system a number of plants must be installed as well as an irrigation system that would infiltrate contaminated groundwater into the treatment cells. For this type of remedial technology, the fundamental design components include the number of plants, placement of the plants, size of cells, and managing the system following construction. In order to assist in designing this type of system, the pilot study previously mentioned would help determine design requirements.

4.2.4.6 Institutional Controls and Requirements

Implementation of a constructed wetland system would not require a 401 Impact Permit if the construction did not impact existing wetlands.

Implementation of a constructed wetland system would likely require a discharge permit normally regulated under NPDES.

4.3 Option 3 – Gas Extraction

4.3.1 Method Description

Landfill gas (LFG) is a product of the degradation of biodegradable wastes. The buildup of LFG in a landfill can cause off-site migration or groundwater contamination. The landfill currently has a passive LFG system consisting of 60 vertical wells which vent the LFG to the atmosphere. The passive system can be converted to an active system by installing new well heads which can be connected to a piping system which will connect to a blower. The blower will create a vacuum which will extract the LFG from the landfill. This reduces the pressure buildup of the LFG to prevent migration and potential groundwater contamination. Additional vertical wells can be installed to increase the effectiveness of the system.

4.3.2 Performance and Reliability

Groundwater contamination from LFG can occur through the following mechanisms:

- Direct contact of groundwater with LFG;
- Rising groundwater or infiltrating water washing contaminants from the vadose zone contaminated by LFG;
- LFG cooling in the soil outside the landfill causing condensate to form, which percolates to the groundwater; and
- Acids in the LFG causing some naturally occurring metals in the soil to dissolve into the groundwater.

LFG moves via convection (pressure build-up in waste) and diffusion (movement from higher concentration to lower concentration). A gas extraction system can reduce LFG migration due to convection. The effectiveness of a gas extraction system in improving groundwater is based on how well the system extracts LFG. Well placement and depth as well the amount of outside air intrusion will affect the performance of the system.

4.3.3 Remediation Timeframe

The success of a gas extraction system improving groundwater is dependant on several factors including well placement and depth, waste saturation, air intrusion into the system, and what percentage LFG is as a source of groundwater contamination. Once a system is designed and installed, it would take a few months to adjust the system to get optimum performance. Once the system is running optimally, it will likely take a few more months to reduce off-site migration and potential groundwater contamination.

4.3.4 Implementation Requirements

The gas extraction system implementation can begin immediately following its design. Depending on the volume and concentration of contaminants in collected LFG, a LFG treatment system may be required.

4.4 Option 4 – In-Situ Isolation

The following methods of In-Situ Isolation will be discussed in further detail below:

- Barrier/Containment Wall
- Maintaining a Consistent Contour with pre-1988 Waste Area
- Increasing Slope of Closed MSW Area
- Stormwater Improvements – Western Half of Landfill
- Stormwater Improvements – Eastern Half of Landfill

4.4.1 Barrier / Containment Wall

4.4.1.1 Method Description

Cut-off wall technology or a slurry wall physical containment technique involves installing barriers to groundwater flow. Alternate physical barrier technologies involve grout curtains, sheet pilings, block displacement, and synthetic membranes. The rational behind installing a physical barrier is to divert either uncontaminated groundwater away from waste sites or contaminated water away from clean areas (Ehrenfield and Bass, 1984). These containment systems also provide for temporary containment while groundwater is removed and treated, and aquifer material is decontaminated.

The physical barrier can be utilized in at least two different approaches. The physical barrier could be placed upgradient of the contamination zone to help limit the amount of water migrating to a sensitive or off-site area. A second possible approach is to place the physical barrier downgradient of the contamination zone, and use in conjunction with a pump and treat system (as documented in **Section 4.3**).

There are three primary types of physical barriers that have been demonstrated to be effective at stopping groundwater migration and flow. These include: bentonite slurry walls, sheet piling, and synthetic membranes.

Slurry walls made of bentonite contain the groundwater, thus treating no particular target group of contaminants. Slurry walls are used to contain contaminated groundwater, divert contaminated groundwater from drinking water intake, divert uncontaminated groundwater flow, and/or provide a barrier for the groundwater treatment system.

These subsurface barriers often consist of a vertically excavated trench that is filled with a slurry. The slurry hydraulically shores the trench to prevent collapse and form a filter cake to reduce groundwater flow. Most slurry walls are constructed of a soil, bentonite, and water mixture; walls of this composition provide a barrier with low permeability and chemical resistance at low cost. Other wall compositions, such as sheet piling, cement, bentonite, and water may be used if greater structural strength is required or if chemical incompatibilities between bentonite and site contaminants exist.

Slurry walls are typically placed at depths less than 50 feet and generally are 2 to 4 feet thick. The most effective application of the slurry wall for site remediation or pollution control is to base (or key) the slurry wall 2 to 3 feet into a low permeability layer such as a clay or bedrock. This "keying in" provides for an effective foundation with minimum leakage potential.

Sheet piling has been used for civil engineering applications for years. A sheet pile barrier can be made from a variety of materials: wood, recast concrete, and steel. Steel is the most common material because of its high durability, low cost, and high flexibility. Sheet pilings are constructed by driving individual sections of interlocking steel sheets into the ground with impact or vibratory hammers to form an impermeable barrier. The retaining steel pile walls flex from water or lateral earth pressure which tightens the interlocks making the connection more water resistant.

Synthetic membranes used for vertical cutoff walls are generally made from high density polyethylene; however, other polymers have been used. Membrane sheets can be continuous, but usually finite length panels that interlock are preferred. The final depth of installation is a function of the ability of the trenching technique.

Synthetic membranes are typically installed in much the same way as the bentonite slurry wall and sheet piling. Trenching machine installation involves the excavation of an unsupported trench with the membrane lowered vertically in the trench and progressively unrolled.

4.4.1.2 Performance and Reliability

Slurry walls are a full-scale technology that has been used for decades as a long-term solution for controlling groundwater seepage and flow. The technology has demonstrated its effectiveness in containing more than 95% of uncontaminated groundwater; however, in contaminated groundwater applications, certain contaminant types may degrade the slurry wall components and reduce the long term effectiveness.

A key factor in installing an effective slurry wall is to anchor the base of the wall in either competent bedrock or a clay with very low permeability. Slurry walls have been used for decades, so the equipment and methodology are readily available and well known; however, the process of designing the proper mix of wall materials to contain specific contaminants is less well developed. Excavation and backfilling of the trench is critical and requires experienced contractors.

Sheet piling and synthetic membrane barriers remove the potential for breakdown from contaminant parameters. Also, no excavation is necessary to install a sheet piling wall.

Factors that may limit the applicability and effectiveness of physical barriers include the following:

- The technology only contains contaminants, or limits groundwater flow, within a specific area
- Soil-bentonite backfills are not able to withstand attack by strong acids, bases, salt solutions, and some organic chemicals (other slurry mixtures can be developed to resist specific chemicals)
- There is the potential for the slurry walls to degrade or deteriorate over time

- Noise and vibration during installation
- Process may not be suitable for soils containing large cobbles and boulders
- Depth limitations
- Keying into rock is not possible with sheet piling technology

The following factors, at a minimum, must be assessed to design effective soil-bentonite slurry walls: maximum allowable permeability, anticipated hydraulic gradients, required wall strength, availability and grade of bentonite to be used, boundaries of contamination, compatibility of wastes and contaminants in contact with slurry wall materials, characteristics (i.e., depth, permeability, and continuity) of substrate into which the wall is to be keyed, characteristics of backfill material (e.g., fines content), and site terrain and physical layout.

Advantages of physical barrier technology in groundwater remediation include the following:

- High level of effectiveness in containing/diverting groundwater
- With sheet piling no excavation is required
- Sheet piling can be removed later if required or desired
- With sheet piling technology, topography and depth to groundwater have little impact
- Diffusive transponder is reduced
- Irregular enclosure shapes are possible
- Continuity of impermeability
- Various methods of installation provide flexibility in design to meet site specific needs.

A geotechnical evaluation of the location where the physical barrier is to be installed must be performed. The key factor in evaluating the effectiveness of a physical barrier is the ability of the system to contain the plume or to minimize flow of groundwater into the waste disposal unit. Therefore, additional geotechnical work, aquifer tests, groundwater monitoring well installation, and groundwater sampling and analysis may be needed to optimize the design.

Performance of a properly designed and installed physical barrier is expected to reduce constituents of concern in groundwater in downgradient areas from the physical barrier itself. The physical barrier will prevent transport of groundwater through landfill wastes and will allow natural attenuation to continue to remediate impacted groundwater from areas downgradient of the physical barrier.

Physical barrier systems do not require regular maintenance to continue operating as designed. Physical barrier systems do not require experienced operator oversight or frequent operational changes to be effective. However, they do require regular monitoring to insure that leaks are not occurring due to poor seals or deterioration of the barrier itself. Additionally, bentonite slurry walls may at some point need to be replaced.

4.4.1.3 Associated Receptor Impacts

Depending on the installation method, a large volume of diverted groundwater may need to be disposed. If the physical barrier is installed upgradient of the waste disposal units, non-impacted groundwater will be diverted and require handling. If the physical barrier is installed downgradient of the waste disposal units, impacted groundwater will have to be disposed and/or treated. Additionally, depending on the exact location, wetlands and stream channels may be impacted.

4.4.1.4 Remediation Time Frame

The remediation timeframe for a physical barrier system will depend on the placement of the barrier itself and MNA processes. Installation of the physical barrier could be placed upgradient of the waste disposal units in an effort to reduce downgradient influx of clean groundwater into the waste units. Cutting off or reducing groundwater migration into the waste units will reduce intermixing of groundwater with leachate, reduce leachate production and dramatically reduce landfill mass. This scenario will assist and promote natural attenuation within the waste disposal units as well as impacted areas of the hydrogeologic regime in the downgradient areas. Timeframes to achieve remedial goals will be limited by natural attenuation processes.

4.4.1.5 Implementation Requirements

Prior to installing any of the types of physical barriers discussed above, an extensive site characterization must be performed in the area of proposed installation in order to determine: the depth to a continuing layer of bedrock or low permeability clay, the geotechnical qualities of the soil, fines content of the soil, and a cross sectional map of both the saturated and vadose zones of the subsurface. The design of the physical barrier must incorporate compensations for the difficulties presented by the site characteristics in order to design and install a successful physical barrier. Additionally, a pilot study may be required to ensure the effectiveness of the proposed physical barrier. For an effective and successful physical barrier, the fundamental design elements include completely capturing the zone(s) of impact within the aquifer and "keying in" to competent bedrock or a very low permeability clay such that migration of groundwater will be stopped and not leak below and through the base of the physical barrier. Therefore, the physical barrier will need to be installed into a low permeability layer lower or into bedrock to prevent plume deflection into lower portions of the uppermost aquifer. Depth to a low permeability layer at the landfill varies between 10 to 15 feet below ground surface.

4.4.1.6 Institutional Controls & Requirements

The County may require permits for construction activities. Also the NCDENR DWM will require modification to the facility operating permit.

4.4.2 Maintaining a Consistent Contour with pre-1988 Waste Area

4.4.2.1 Method Description

Maintaining consistent contour elevations across the waste disposal units where C&D waste is not currently being placed entails basic maintenance to those areas where ditches, slumps, and sinkholes have formed from waste decomposition. Maintenance would involve filling or grading over only those anomalous surface deficiencies that facilitate the influx of water into the waste mass.

Maintaining a consistent contour would involve a continuous process of inspection and backfilling on a semi-annual or annual basis for existing or potential surface water collection locations followed by timely addition of backfill soil and reseeding.

4.4.2.2 Performance and Reliability

This process will reduce groundwater contamination by reducing vertical percolation of pounded rain water into the waste mass which can produce leaching.

4.4.2.3 Remediation Timeframe

Estimated annual costs to ensure a consistent contour on the landfill cap is $5,000 per year, which would be part of the post-closure care for the MSW landfill.

4.4.3 Increasing Slope of Closed MSW Area

4.4.3.1 Method Description

Increasing the slope of the cap will decrease the infiltration of stormwater into the MSW waste and reduce the potential for groundwater contamination. The eastern portion of the landfill is where the current C&D waste disposal is being conducted. The C&D waste has been placed over the existing MSW landfill cap and has increased the slope in this area. The waste placement also provides an additional barrier to stormwater infiltrating into the MSW landfill.

The slopes in the western portion of the MSW landfill are relatively flat with a majority of the area at a slope of approximately 5 to 6 percent. Increasing the slope in this area would involve moving the current C&D waste placement operations from the eastern portion of the landfill to the western portion. The C&D waste placement would increase the slope in this area and also provides an additional barrier to stormwater infiltrating into the MSW landfill.

4.4.3.2 Performance and Reliability

Increasing the slope of the cap will reduce the amount of stormwater infiltrating into the waste which will reduce and possibly eliminate a source of water which comes in contact with the waste and can produce leaching.

4.4.3.3 Remediation Timeframe

Increasing the cap slope by placing C&D waste to reduce stormwater infiltration will be based on how much C&D waste the facility receives. The more C&D waste the facility receives, the sooner the western portion of the landfill will be covered and the slope increased. This in turn will reduce the amount of water coming into contact with the waste which will reduce potential groundwater contamination.

4.4.3.4 Implementation Requirements

Filling in the western portion of the landfill can begin once the following items are completed:

- Design grading plan and stormwater controls;
- Grade existing C&D filling area on the eastern portion of the landfill to promote positive drainage; and
- Construct necessary stormwater controls in the western portion of the landfill.

4.4.4 Stormwater Improvements – Western Half of Landfill

4.4.4.1 Method Description

Improving the stormwater structures on the western half of the landfill will decrease the infiltration of stormwater into the ground which could come in contact with the MSW waste and produce leaching. The general groundwater flow direction is to the north to northeast. Reducing the amount of stormwater infiltration into the ground south and west of the landfill will reduce the groundwater level under the landfill and reduce the potential for groundwater coming in contact with the waste. Structures that would be improved include the sedimentation pond located just north of the landfill, and the perimeter ditch which flows west along the southern portion of the landfill and then turns and flows north along the western edge of the landfill, ultimately discharging to Jerry's Creek.

The sedimentation pond just north of the landfill would be filled with low permeability backfill. The remainder of this "horseshoe-shaped" area will be backfilled with low permeability fill material.

The perimeter ditch has filled up with silt and sediment and has a relatively flat slope. The ditch would be re-graded to improve its slope and flow. This would in turn reduce how much stormwater would infiltrate from the ditch and become groundwater which could come in contact with the waste and potentially produce leaching. During periods of high groundwater, the ditch would intercept a portion of the groundwater and divert it around the landfill.

4.4.4.2 Performance and Reliability

Improving the flow in the perimeter ditch and redesigning the sedimentation pond area will reduce the amount of stormwater infiltrating into the ground which will reduce and possibly eliminate a source of water which comes in contact with the waste and produce leaching from the waste.

4.4.4.3 Remediation Timeframe

Improvements to groundwater could begin within a few months of completing the stormwater improvements. Once the improvements are made, the groundwater level under the landfill should decrease which will reduce the amount of groundwater coming into contact with the waste which will reduce groundwater contamination.

4.4.4.4 Implementation Requirements

Stormwater improvements can begin immediately following their design.

4.4.5 *Stormwater Improvements – Eastern Half of Landfill*

4.4.5.1 Method Description

Improving the stormwater structures on the eastern half of the landfill will decrease the infiltration of stormwater into the ground which could come in contact with the MSW waste and produce leaching. The general groundwater flow direction is to the north to northeast. Reducing the amount of stormwater infiltration into the ground south of the landfill will reduce the groundwater level under the landfill and reduce the potential for groundwater coming in contact with the waste. Structures that would be improved include the perimeter ditch which flows west along the southern portion of the landfill, installing a new ditch between the southern access road and property line, and removing the pond located south of the maintenance building.

The perimeter ditch has filled up with silt and sediment and has a relatively flat slope. The ditch would be re-graded to improve its slope and flow and be extended as necessary to convey stormwater away from the landfill. A portion of the perimeter ditch may be just within the limits of waste placement. Test pits will be excavated to confirm or deny this and the ditch location adjusted as necessary to be located outside the limits of waste. This would reduce how much stormwater would infiltrate from the ditch and become groundwater which could come in contact with the waste and potentially produce leaching.

A new ditch will be installed between the southern access road and the property boundary. This ditch would intercept stormwater prior to reaching the landfill at a location farther away from the landfill than the existing perimeter ditch. During periods of high groundwater, the ditch would intercept a portion of the groundwater and divert it around the landfill.

The pond south of the maintenance building would be removed. This would reduce infiltration into groundwater and therefore reduce the groundwater level under the landfill.

4.4.5.2 Performance and Reliability

Improving the flow in the perimeter ditch, installing the new ditch, and removing the pond will reduce the amount of stormwater infiltrating into the ground which will reduce and possibly eliminate a source of water which comes in contact with the waste and produce leaching.

4.4.5.3 Remediation Timeframe

Improvements to groundwater could begin within a few months of completing the stormwater improvements. Once the improvements are made, the groundwater level under the landfill should decrease which will reduce the amount of groundwater coming into contact with the waste which will reduce groundwater contamination.

4.4.5.4 Implementation Requirements

Stormwater improvements can begin immediately following their design.

4.5 Remediation Costs

The following is a summary of costs for the options described above.

Table 3
Detailed Evaluation of Retained Remedial Action Alternatives

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OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
1 – Monitored Natural Attenuation (MNA) of GW	MNA provides a long term method of reducing impact to environment. MNA will not eliminate potential for human exposure, groundwater & surface water will be monitored.	MNA is allowable under current federal and state regulations.	**Short:** MNA will provide no short term reductions in GW impact. **Long:** MNA will provide method to monitor long term attenuation mechanisms, reduce impact to environment and reduce potential for future human exposure. Reductions will be gradual but permanent.	Long term reductions in toxicity of down gradient GW impact are possible through MNA.	Easily implemented, no significant access problems or special engineering constraints required. The GW remediation may take 20-30 years or more to achieve RGs.	Capital Cost engineering, permitting, groundwater flow modeling, and installing additional monitoring wells as required is approx. **$120,000** Annual Maintenance, GW sampling & reporting is approx. **$40,000/yr** Site Closure is approx: **$35,000** 10 yr total: Approx. **$555,000** 30 yr total: Approx. **$1,355,000**	MNA is a common and often used remedial option. Must prove viability of MNA. Concurrence of MNA by downgradient property owners may be required.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
2A – Groundwater Collection with Off-Site Disposal	A groundwater recovery system will capture COCs in groundwater near the source and reduce down gradient migration and protect down gradient groundwater and surface water exposures.	Groundwater recovery and disposal as a COC mass recovery and containment technology is a demonstrated and often used technology, and is acceptable to regulators.	**Short**: CoCs will be recovered from groundwater recovery system. There may be short term reductions in GW impact. **Long**: GW recovery reduces and possibly eliminates COCs, reduces impact to environment, and reduces potential for future human exposure. Reductions may be gradual but permanent.	Short term reductions of volume, toxicity, and mobility are attainable with a GW recovery and treatment system. Long term reductions in toxicity of GW impact are likely.	Will require hauling/discharge permit. System installation may take less than four (4) months. GW remediation estimated to take 10 - 30 years or more to achieve RGs.	Capital Cost engineering, tests, and recovery system is approx. $300,000 Annual Maintenance, GW sampling, 100gpm groundwater disposal & reporting is approx. **$1,500,000+/yr** Site Closure is approx: **$35,000** 10 yr total: Approx. **$15,000,000** 30 yr total: Approx. **$45,000,000**	GW recovery and treatment and a permitted discharge at an off-site permitted facility are acceptable remedial options.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals
gpm – gallons per minute

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

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OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
2B – Groundwater Collection with On-Site Water Treatment System and On-Site Disposal	A groundwater recovery system will capture COCs in groundwater near the source and reduce down gradient migration and protect down gradient groundwater and surface water exposures.	Groundwater recovery and treatment as a COC mass recovery and containment technology is a demonstrated and often used technology, and is acceptable to regulators.	**Short**: COCs will be recovered from groundwater recovery system. There may short term reductions in GW impact. **Long**: GW recovery reduces and possibly eliminates COCs, reduces impact to environment, and reduces potential for future human exposure. Reductions may be gradual but permanent.	Short term reductions of volume, toxicity, and mobility are attainable with a GW recovery and treatment system. Long term reductions in toxicity of GW impact are likely.	Will require a discharge permit and possible bench and/or pilot testing. System installation may take less than four (4) months. GW remediation estimated to take 10 - 30 years or more to achieve RGs.	<u>Capital Cost</u> engineering, tests, recovery system, and treatment system is approx. **$750,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$200,000/yr** <u>Site Closure</u> is approx: **$77,000** <u>10 yr total:</u> Approx. **$3,000,000** <u>30 yr total:</u> Approx. **$7,000,000**	GW recovery and treatment and a permitted discharge into a water body are common and often used remedial options.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

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OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
2C – Groundwater Collection with Constructed Wetland and On-Site Disposal	A groundwater recovery system will capture COCs in groundwater near the source and reduce down gradient migration and protect down gradient groundwater and surface water exposures. Will require limited access to constructed wetlands area.	Groundwater recovery and treatment as a COC mass recovery and containment technology is a demonstrated and often used technology, and is acceptable to regulators. Constructed wetlands is a newer technology, but is favorable as an improvement and wildlife habitat.	**Short:** COCs will be recovered from groundwater recovery system. There may short term reductions in GW impact. **Long:** GW recovery reduces and possibly eliminates COCs, reduces impact to environment, and reduces potential for future human exposure. Reductions may be gradual but permanent.	Short term reductions of volume, toxicity, and mobility are attainable with a GW recovery and treatment system. Long term reductions in toxicity of GW impact are likely.	Will require discharge permit and possible bench and or pilot testing. System installation may take less than six (6) months. GW remediation estimated to take 10 - 30 years or more to achieve RGs.	<u>Capital Cost</u> engineering, tests, recovery system, and constructed wetlands is approx. **$1,300,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$110,000/yr** <u>Site Closure</u> is approx: $85,000 <u>10 yr total:</u> Approx. **$2,500,000** <u>30 yr total:</u> Approx. **$4,700,000**	GW recovery and treatment and a permitted discharge into a water body are common and often used remedial options. Constructed wetlands is a newer technology, but, is favorable as an improvement and wildlife habitat.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
3 – Gas Extraction: Convert existing vents to wells and install additional wells to extract landfill gas (LFG). **Option 1 – MNA will also have to be performed.**	The system will extract LFG from the landfill and reduce the pressure buildup of the LFG to prevent migration and potential groundwater contamination.	Extracting LFG to reduce LFG migration and contamination of GW is a demonstrated and often used technology, and is acceptable to regulators.	**Short:** There should be short term reductions in GW impact. **Long:** Extracting the LFG will reduce a source of GW contamination. Eventually the landfill will stop producing LFG at a rate where migration outside of the landfill will no longer be a concern.	Short term reductions of volume, toxicity & mobility is attainable with a gas extraction system Long term reductions in toxicity of GW impact are likely.	Will require air permit and possible bench and or pilot testing. System installation may take less than six (6) months. GW remediation estimated to take 10 - 30 years or more to achieve RGs.	<u>Capital Cost</u> engineering, tests, recovery wells, and treatment system is approx. **$500,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$170,000/yr** <u>Site Closure</u> is approx: **$25,000** <u>10 yr total:</u> Approx. **$2,225,000** <u>30 yr total:</u> Approx. **$6,000,000**	A gas extraction systems is a common and often used remedial option.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

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OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
4A – In-Situ Isolation: Install a 2,200' Long, 30' Deep Barrier Wall **Option 1 – MNA will also have to be performed.**	Reduction of water contacting the waste source in the landfill will reduce and eventually nearly eliminate COCs from entering groundwater.	Management of storm and surface water is considered a best management practice.	**Short:** Redirection of storm, surface and groundwater will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	Long term reductions in toxicity of down gradient GW impact are possible through MNA.	Easily implemented, no significant access problems or special engineering constraints required. May take up to six (6) months or more to grade the landfill cap and/or install a barrier wall; the GW remediation may take 20-30 years or more to achieve RGs.	<u>Capital Cost</u> engineering and barrier wall installation is approx. **$615,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$45,000/yr** <u>Site Closure</u> is approx: **$35,000** <u>10 yr total:</u> Approx. **$1,100,000** <u>30 yr total:</u> Approx. **$2,000,000**	GW redirection with barrier walls and/or landfill grading is common and often used as a remedial option.
4B – In-Situ Isolation: Maintain Consistent Contours with pre-1988 Waste Area **Option 1 – MNA will also have to be performed.**	Reduction of water contacting the waste source in the landfill will reduce and eventually nearly eliminate COCs from entering groundwater.	Management of storm and surface water is considered a best management practice.	**Short:** Redirection of storm, surface and groundwater will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent	Long term reductions in toxicity of down gradient GW impact are possible through MNA.	Easily implemented, no significant access problems or special engineering constraints required. May take up to six (6) months or more to grade the landfill cap and/or install a barrier wall; the GW remediation may take 20-30 years or more to achieve RGs.	<u>Annual</u> Contouring, Maintenance, GW sampling & reporting is approx. **$45,000/yr** <u>Site Closure</u> is approx: **$35,000** <u>10 yr total:</u> Approx. **$485,000** <u>30 yr total:</u> Approx. **$1,385,000**	GW redirection with barrier walls and/or landfill grading is common and often used as a remedial option.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
4C – In-Situ Isolation: Increase Slope of Closed MSW Area **Option 1 – MNA will also have to be performed**	Reduction of water contacting the waste source in the landfill will reduce and eventually nearly eliminate COCs from entering groundwater.	Management of storm and surface water is considered a best management practice.	**Short:** Redirection of storm and surface water will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	**Short:** Redirection of storm and surface water will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	Easily implemented, no significant access problems or special engineering constraints required. May take up to six (6) months or more to grade the landfill cap; the GW remediation may take 20-30 years or more to achieve RGs.	<u>Capital Cost</u> engineering and stormwater control installation is approx. **$25,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$45,000/yr** <u>Site Closure</u> is approx: **$35,000** <u>10 yr total:</u> Approx. **$510,000** <u>30 yr total:</u> Approx. **$1,410,000**	GW redirection with landfill grading and stormwater improvements is common and an often used remedial option.
4D – In-Situ Isolation: Stormwater Improvements on Western Half of Landfill. **Option 1 – MNA will also have to be performed.**	Reduction of water contacting the waste source in the landfill will reduce and eventually nearly eliminate COCs from entering groundwater.	Management of storm and surface water is considered a best management practice.	**Short:** Redirection of storm and surface water will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	**Short:** Redirection of storm and surface water will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	Easily implemented, no significant access problems or special engineering constraints required. May take up to six (6) months or more to grade the landfill cap; the GW remediation may take 20-30 years or more to achieve RGs.	<u>Capital Cost</u> engineering and stormwater control installation is approx. **$30,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$45,000/yr** <u>Site Closure</u> is approx: **$35,000** <u>10 yr total:</u> Approx. **$515,000** <u>30 yr total:</u> Approx. **$1,415,000**	GW redirection with landfill grading and stormwater improvements is common and an often used remedial option

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

Table 3 (Cont.)
Detailed Evaluation of Retained Remedial Action Alternatives

OPTION	OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT	COMPLIANCE WITH REGULATORY AND PERMITTING REQUIREMENTS	EFFECTIVENESS (SHORT AND LONG TERM)	REDUCTIONS OF TOXICITY, MOBILITY OR VOLUME	IMPLEMENTABILITY (TECHNICAL & LOGISTICAL)	COST	STATE AND COMMUNITY ACCEPTANCE
4E – In-Situ Isolation: Stormwater Improvements on Eastern Half of Landfill. **Option 1 – MNA will also have to be performed.**	Reduction of water contacting the waste source in the landfill will reduce and eventually nearly eliminate COCs from entering groundwater.	Management of storm and surface water is considered a best management practice.	**Short:** Redirection of storm and surface water will immediately begin to reduce migration of COCs. **Long:** Reductions will be gradual but permanent.	Long term reductions in toxicity of down gradient GW impact are possible through MNA.	Easily implemented, no significant access problems or special engineering constraints required. May take up to six (6) months or more to grade the landfill cap; the GW remediation may take 20-30 years or more to achieve RGs.	<u>Capital Cost</u> engineering and stormwater control installation is approx. **$30,000** <u>Annual</u> Maintenance, GW sampling & reporting is approx. **$45,000/yr** <u>Site Closure</u> is approx: **$35,000** <u>10 yr total:</u> Approx. **$515,000** <u>30 yr total:</u> Approx. **$1,415,000**	GW redirection with stormwater improvements is common and an often used remedial option.

Notes:
GW – Groundwater
COC – Contaminant of Concern
RGs – Remedial Goals

5. ASSESSMENT OF POTENTIAL METHODS OF GROUNDWATER CORRECTIVE MEASURES

5.1 Option 1 - Monitored Natural Attenuation

Monitored Natural Attenuation (MNA) would be an appropriate method of restoring groundwater quality at the landfill based on the existing hydrogeologic conditions as well as the previously discussed risk assessment and analysis. Surface water quality could be monitored and the results compared to the existing 2B Standards. MNA could be the central component of the landfill's selected remedy while incorporating one or more of the other feasible treatment options previously discussed such as maintaining a consistent contour over the waste disposal units. The dispersion, natural attenuation, and continued monitoring option would be economically feasible and within the resources of Edgecombe County. Continuing the existing groundwater monitoring event program could also establish the concentration trend over time.

5.2 Option 2 – Groundwater Collection with Off-Site Disposal or On-Site Treatment and On-Site Disposal

5.2.1 Option 2A – Groundwater Collection with Off-Site Disposal

With the groundwater collection with off-site disposal method, the contaminated water would be pumped out of the ground and then pumped off-site to the local waste water treatment facility and treated. The groundwater collection systems may also allow for variable hydrogeological (i.e. seasonal water elevations changes) conditions. The groundwater collection with off-site disposal process can be used quite effectively in combination with MNA. However, these systems are costly to install and require annual maintenance costs.

5.2.2 Option 2B – Groundwater Collection with On-Site Treatment

With the groundwater collection with on-site treatment method, the contaminated water would be pumped out of the ground and then pumped to an on-site treatment system and treated physically, chemically, or biologically. The groundwater collection systems may also allow for variable hydrogeological (i.e. seasonal water elevations changes) conditions. The groundwater collection with on-site treatment process can be used quite effectively in combination with MNA. Again however, these systems are expensive to install and with the on-site treatment option, annual maintenance costs are significantly higher than other possible remedial options.

5.2.3 Option 2C – Groundwater Collection with Constructed Wetland and On-Site Disposal

With the groundwater collection with constructed wetland treatment, the contaminated water would be pumped out of the ground and then pumped through a wetland for treatment via biotic and abiotic activity. The effectiveness of the constructed wetland depends greatly on environmental conditions such as temperature and concentration of the contaminants in the groundwater. The groundwater collection with constructed wetlands and on-site disposal can also be used effectively in combination with MNA.

While this is a lower cost option and within range of the financial resources of Edgecombe County, the timeframe to achieve remedial goals can be lengthy.

5.3 Option 3 Gas Extraction System

Implementing a gas extraction system would involve the upgrade of the already existing passive gas extraction system which vents the LFG to the atmosphere. A blower system would create a vacuum which will extract the LFG from the landfill. Implementation of this method may have a direct effect on groundwater quality. Actively extracting decomposition gas removes VOCs and sometimes other constituents from the subsurface which reduces interaction of these constituents with the uppermost aquifer in the vadose and capillary fringe zones, thereby improving groundwater quality. In addition, there may be potential for future use of the gas collected as a source of energy. Technologies exist that could turn captured methane gas into electricity which, in some cases can be sold back to the local utility to generate income for the County. However, the viability of this option is dependant on the volume of decomposition gas being produced by the landfill. If volumes are low, the income gained from lower electricity production is often offset by the costs of implementing such a system.

5.4 Option 4 – In Situ Isolation

5.4.1 Optiojn 4A – Barrier/Containment Wall

5.4.1.1 Downgradient Physical Barrier

The cut-off wall or physical barrier technology may be able to provide flow containment to the groundwater exceeding the 2L Standard. Impacted groundwater upgradient of the barrier wall would require recovery and treatment. However, the waste disposal units are so close to the creek that if implemented as the selected remedy, a physical barrier would have to be installed into the flood plain areas of the creek. The limits of waste almost extend to the alluvial flood plain deposit of the creek and therefore there is very limited access to install a physical barrier between the northern edge of the waste disposal units and the creek. Application of this technology would involve excavation into the flood plain of the creek. Excavation into the flood plain areas of the creek may require special permitting for impacting protected waters of the U.S. and special design techniques would have to be employed to insure the effectiveness of the physical barrier at stopping further downgradient migration. This would be difficult due to the fact that the barrier would have to be built in a constantly saturated alluvial deposit.

5.4.1.2 Upgradient Physical Barrier

Because of the shallow depth to groundwater in the upgradient region of the Edgecombe County Landfill, as well as the available space between the waste disposal units and the southern property boundary, an upgradient physical barrier would be an option to assist in restoring groundwater quality at the landfill. Diverting the flow of groundwater around the waste disposal units would eliminate interaction of the groundwater with the waste mass, thereby reducing leachate production. A likely option for this type of barrier at the landfill would be a slurry wall.

In order to be effective at diverting groundwater flow, subsurface physical barriers must be anchored into either competent low permeability bedrock or a low permeability confining unit. The existing subsurface conditions at the landfill are also favorable for this type of remedy. If a slurry wall were selected as part of the landfill's remedy, it could be anchored into the Tertiary-age marine clay layer (Yorktown Formation) encountered at 3 to 20 feet below the original ground surface which may be acting as a confining layer below the landfill.

Additionally, there are currently stormwater diversion trenches which run parallel to the direction of groundwater flow on both sides of the waste disposal units. These trenches could be expanded/improved to serve as groundwater diversion ditches to transport groundwater diverted around the sides of an upgradient physical barrier wall. Water diverted in the upgradient region of the landfill before interaction with the waste disposal units would likely not require pre-treatment before discharging to the downgradient receiving creek which may also make this option economically feasible to the County. If proper site conditions exist and when properly installed, upgradient physical barriers can effectively reduce leachate production, reduce landfill mass, and ultimately restore groundwater quality at landfill facilities.

5.4.2 Option 4B – Maintaining Consistent Contour Elevations

Maintaining consistent contour elevations would involve a continuous process of inspection and backfilling on a semi-annual or annual basis for any existing or potential surface water collection locations followed by timely addition of backfill soil and reseeding. This process will reduce groundwater contamination by reducing vertical percolation of stormwater into the waste mass which can produce leaching. This process in conjunction with another method would help in the restoration of groundwater quality at the site.

5.4.3 Option 4C – Increasing Slope of Closed MSW Area

Increasing the slope of the closed MSW area would be an appropriate method of restoring groundwater quality at the landfill in conjunction with another method based on the existing topographic conditions as well as the previously discussed risk assessment and analysis. The cost and maintenance required is low, and it would decrease stormwater infiltration into the landfill cell, thereby reducing landfill mass.

5.4.4 Option 4D – Stormwater Improvements – Western Half of Landfill

Stormwater improvements made at the landfill would be an appropriate method of restoring groundwater quality at the landfill in conjunction with another method based on the existing topographic conditions as well as the previously discussed risk assessment and analysis. The cost is low, and it would decrease stormwater infiltration into the landfill western half of the landfill as well as decrease sedimentation to Jerry's Creek.

5.4.5 Option 4E – Stormwater Improvements – Eastern Half of Landfill

Stormwater improvements made at the landfill would be an appropriate method of restoring groundwater quality at the landfill in conjunction with another method based on the existing topographic conditions as well as the previously discussed risk assessment and analysis. The cost is low, and it would decrease stormwater infiltration into the landfill eastern half of the landfill as well as decrease sedimentation to Jerry's Creek.

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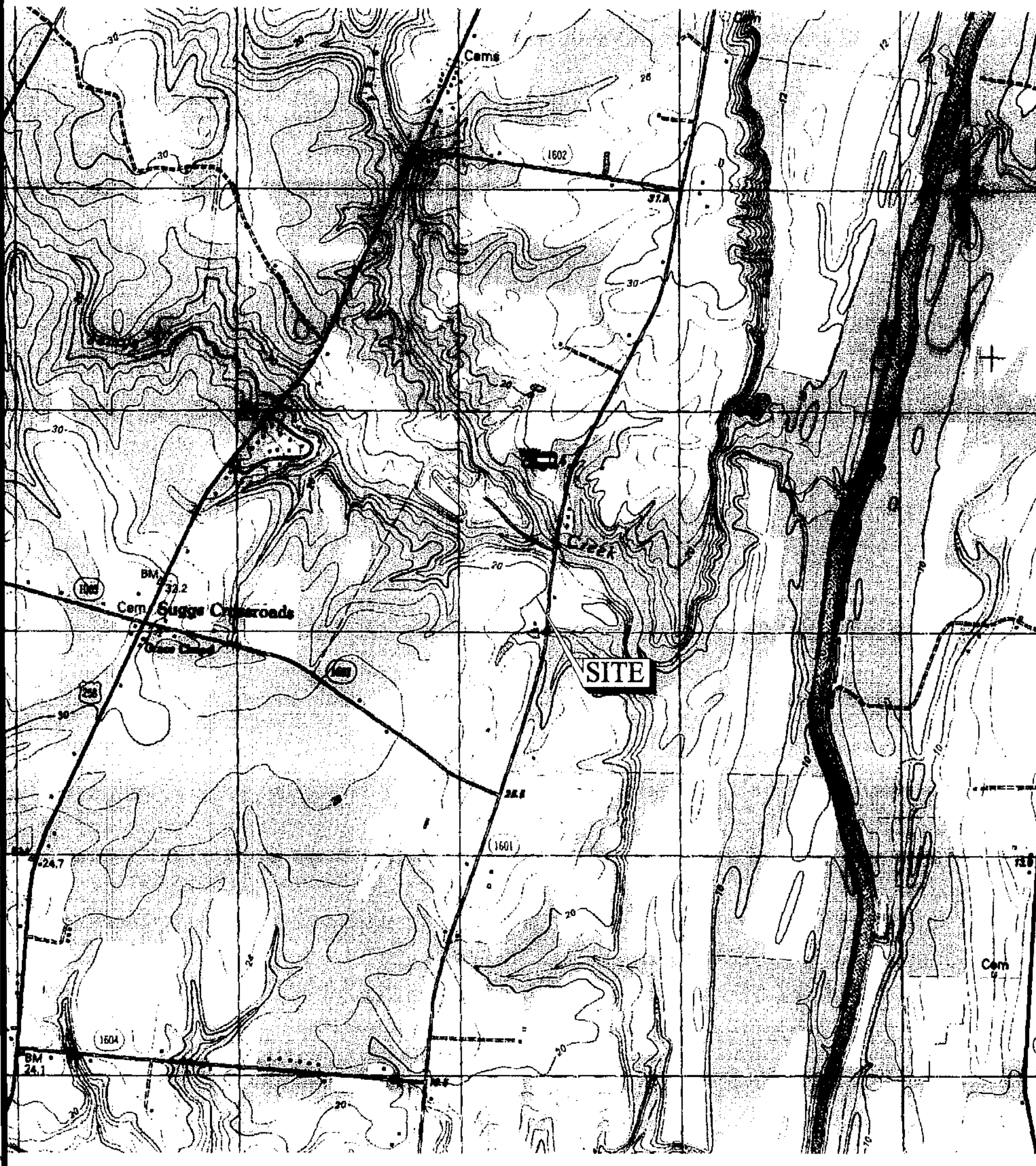
FIGURES



TOPO SOURCE: NCGS DRG
OLD SPARTA, NC (035077G5) DATED 1981

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PROJECT NO: 1054-07-241			

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